PUAF 741

Global Environmental Problems

FINAL EXAM

Tuesday, 19 December 2000, 4:30–7:30 pm, room 1206 VMH

Please enter your student number here: _____
Do not enter your name anywhere on this exam (5-point penalty!)

This exam contains 100 points. You have three hours to complete the exam. Allocate your time accordingly (i.e., 9 minutes per 5-point problem).

This is a closed-book exam, except for one sheet of notes. Useful information is attached. Calculators are allowed; computers are not.

Enter all answers and do all your work on this exam. If you need more space, use the back side of the sheet.

Quantitative questions should include an appropriate number of significant digits and the proper units. **Circle final answers**. Partial credit for incorrect answers can be given only if you show your work. If you need a number you can't find or derive, define a symbol for it or take a guess as to its value and continue. If you don't have time to complete a problem but think you know how to do it, describe the steps. If you know your answer is wrong, say so. If you're uncertain about the nature of the question, ask me.

Qualitative questions should be answered as precisely and succinctly as possible. Complete, polished sentences are not necessary; bullets or "talking points" are fine. **Your handwriting must be legible.**

Exam scores and course grades will be posted on the course web site.

Good luck!

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1. The population of Guatemala grew from 3.0 to 12.0 million from 1950 to 2000.

   A. What was the average growth rate over this period? (3 points)

   B. The death rate averaged 7.3 deaths per year per 1000 people over this period. What was the average birth rate? (3 points)

   C. If the population continued growing at the rate calculated in part A, in what year would it reach 24 million? (3 points)

   D. According to one scenario, the population of Guatemala will level off at about 30 million before 2050, when the average life expectancy will reach 75 years. Roughly how many children will be born in 2050 in this scenario? (3 points)

2. Someone wrote that "We could deal with the CO_2 problem quite easily by using it to soften water for agriculture. Water is hard in most of the U.S.; softening it would use all the CO_2 emitted by the burning of fossil fuels." Evaluate this claim. (15 points)

   "Hard" water contains high concentrations of dissolved calcium. Hardness is measured in grains per gallon (GPG) of $CaCO_3$; 1 grain = 65 mg. Soft water has less than 1 GPG; *very* hard water contains 100 GPG. Carbon dioxide can be used to precipitate the calcium as solid $CaCO_3$ (calcite). The U.S. emits 5.3 Gt/y of CO_2 from fossil-fuel burning and withdraws about 400 billion gallons of water per day.

   (Ca in hard water is not from dissolved $CaCO_3$. Because the concentration of Ca is measured by precipitating it as $CaCO_3$, it is reported in terms of the amount of $CaCO_3$ that could be precipitated.)

3. A recent report by the U.S. Global Change Research Program includes the following "key findings": (a) temperatures will rise 5-10 ºF over the next 100 years, with temperatures increasing more in the winter than the summer; (b) heavy and extreme precipitation events will become more frequent, yet some regions will get drier; (c) forest productivity is likely to increase over the next several decades, but possibly decrease over the longer term; (d) coastal wetland area will be reduced and coastal settlements will be at increased risk. Explain the origin of these findings. (15 points)

4. The Three Gorges Dam, which is currently being constructed in China, will provide about 18,000 MW of hydroelectric power after it is completed. The dam has been very controversial; the reservoir will flood important historical artifacts and structures, and it will displace between one and two million people.

   The alternative would have been coal-burning power plants. Estimate the carbon emissions avoided by Three Gorges. Assume that coal is 75% carbon, releases 28 GJ of heat per ton, and a net efficiency of 30 percent. If the “externality cost” of carbon emissions is $100/tC, what is the corresponding benefit of Three Gorges per displaced person? (15 points)

5. Why did the ozone hole form over Antarctica and not elsewhere? In other words, why did ozone depletion manifest itself as a hole in that particular region rather than as a thinning in the global ozone shield overall? If ozone depletion is confined to this completely unpopulated area, why were we so concerned about it? (10 points)

6. The wind turbines at Carmarthen Bay, Wales, cost $500,000 fully installed, have a rotor diameter of 22 m, and produce up to 300 kW of electricity. Of course, the wind speed is not always high enough to allow the turbines to produce 300 kW; the capacity factor (average output divided by maximum output) is 0.38. Maintenance and operations costs average about $5,000/y per turbine.

   A. Very roughly, what is the cost of the electricity produced by these turbines? Assume a capital charge factor of 10 percent per year. (10 points)

   B. The center of the rotor is 22 m above the ground. Compare the height of the turbine with the height of Van Munching Hall. (3 points)

7. In 1990, wet deposition of anions in the eastern U.S. (east of the Mississippi River) averaged 22.06 kg/ha of SO_4^{2-} and 14.18 kg/ha of NO_3^-. Average precipitation was 122.7 cm.

   A. Where did most of this sulfate and nitrate come from? (5 points)

   B. Characterize the relative importance of SO_2 and NO_x, as contributors to acid rain. (5 points)

C. Ignoring the presence of other anions and cations (other than H^+), what was the average pH of rain? (5 points)

D. Aside from acid rain, what other environmental effects do SO_2 and NO_x emissions have? (5 points)

POSSIBLY USEFUL INFORMATION

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1 meter (m) = 3.281 feet (ft)

1 mile (mi) = 1609 m = 5280 ft

1 hectare (ha) = 10^4 m^2 = 2.47 acres

1 m^3 = 1000 liter (L) = 1 te(H_2O)

1 gallon (gal) = 3.754 L

1 barrel (bbl) = 42 gal

1 kilogram (kg) = 2.205 pounds (lb)

1 tonne (te) = 1000 kg

1 mole = $6.02 \cdot 10^{23}$ molecules

1 mole(gas) = 22.4 L @ STP

1 hour (hr) = 3600 seconds (s)

1 year (yr) = $3.155 \cdot 10^7$ s

1 Joule (J) = $kg \cdot m^2/s^2$

1 BTU = 1055 J

1 kilowatt-hour (kWh) = 3.6 MJ

1 Watt (W) = 1 J/s

1 horsepower (hp) = 746 W

Kelvin (K) = degrees Celsius + 273

$S = F \cdot \tau$

$S(t) = S(0) \cdot e^{rt} = S(0) \cdot (1 + i)^t$

$i = [S(t)/S(0)]^{1/t} - 1 = e^r$

$r = \ln[S(t)/S(0)]/t = \ln(1+i)$

$\log(a \cdot b) = \log(a) + \log(b)$

$pH = -\log_{10}[H^+]$

$[H^+]$ = moles(H^+) per liter H_2O

area of Earth = $5.10 \cdot 10^{14}$ m^2

mass of oceans = $1.35 \cdot 10^{21}$ kg

$(1 - \alpha)\, \pi R^2\, \Omega = 4\pi R^2\, \sigma T^4$

$\sigma = 5.67 \cdot 10^{-8}$ W/m^2K^4

Ω = 1370 W/m^2

$\Delta T = \lambda\, \Delta F$; λ = 0.3 to 1 $K/(W/m^2)$

$\Delta F_{CO2} = 6.3 \log_e (C/C_0)$ W/m^2

mass of atmos. = $5.14 \cdot 10^{18}$ kg

moles of dry air = $1.78 \cdot 10^{20}$

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k = 10^3; M = 10^6; G = 10^9; T = 10^{12}; P = 10^{15}; E = 10^{18}

m = 10^{-3}; μ = 10^{-6}; n = 10^{-9}; p = 10^{-12}; f = 10^{-15}; a = 10^{-18}

Atomic weights: H = 1; C = 12; N = 14; O = 16; S = 32; Ca = 40
